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AUTHOR Hammrich, Penny L.

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ABSTRACT

As a result of the new era in science education reform, professional associations in science such as the American Association for the Advancement of Science (AAAS) have developed science standards for grades K-12. This paper describes a model for utilizing the AAAS Project 2061 benchmarks for these standards in a science methods course. The course was divided among four phases, each building on the previous one. They are as follows: (1) Confront and Challenge, designed to extend teacher candidates' knowledge of national reform movements in science education; (2) Application, in which teacher candidates apply the principles of Science For All Americans (SFAA) and the Project 2061 benchmarks in curriculum design, instruction, and assessment; (3) Evaluation, where teacher candidates evaluate instructional resources by applying the SFAA principles and benchmarks; and (4) Sharing, in which teacher candidates participate as teachers in carrying out lessons they have designed using the recommended content and pedagogy of the benchmarks. Teacher candidates' feedback and reflections show how the content and pedagogical goals of the benchmarks were successfully integrated into their thoughts on the nature of science and science teaching. Contains 11 references. (PVD)

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Penny L. Hammrich, Ph.D.
Assistant Professor Science Education
337 Ritter Hall (003-00)
Temple University
Philadelphia, PA 19122
(215) 204-1520 phone #
(215) 204-1414 fax #
phammric@thunder.ocis.temple.edu

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RUNNING HEAD: Teaching for Excellence

A paper presented at the annual meeting of the Association for the Education of Teachers in Science, January, 1996, Cincinnati, OH

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Teaching for Excellence in K-8 Science Education:

Using Project 2061 Benchmarks for More Effective Science Instruction

As teacher educators, we are all searching for the very best models of instruction to facilitate teacher candidates' conceptions of what it is to teach effectively. Remembering the reform of the 1960's, educators are reminded of the all too forgotten "here today, gone tomorrow" sentiment that followed. As Gerry Wheeler (1996) states, *Systemic reform has a temporal character*. It is not enough to have great materials and workshops for teachers. Current science education reforms seek to promote systemic educational resilience for all students by adopting specific content and process standards.

Professional associations in science such as the National Resource Council (NRC) and the American Association for the Advancement of Science (AAAS) have developed science standards for grades K-12. This national movement has trickled down to state and local boards of education with the development of state and local science curriculum standards.

As a result of the new era of reform, Colleges of Education across the country are incorporating the curriculum standards into their science methods courses. As a science teacher educator, I am aware of how the science standards movement is affecting K-12 science education. The standards movement also has implications for the preparation of teacher candidates. Utilizing the frameworks of the standards movement in science methods courses is an important step towards developing scientific literacy for all Americans. By providing a model in the use of the AAAS Project 2061 benchmarks in my science methods course, teacher candidates were able to successfully analyze, integrate and utilize both "content and pedagogy" into the design of lessons and curriculum. This

background provided the teacher candidates with the skills and knowledge to incorporate the benchmarks in the development and implementation of teaching 4th grade science. Teacher candidates were also invited to lead and facilitate an in-service program showing elementary teachers how to incorporate the benchmarks in their science classes.

It has been argued that teacher candidates need to gain an understanding of how science works (Keeports & Morier, 1994; Ganem, 1993; Bates and Culpepper, 1991; Rutherford & Algren, 1990). This is especially true for elementary teacher candidates because of their limited science background. By successfully infiltrating the benchmarks into science methods courses, teacher candidates will have a new and better understanding of science and how science is taught.

In this article, I describe a model for utilizing the benchmarks in a science methods course. Teacher candidates' feedback and reflections show how the content and pedagogical goals of the benchmarks were successfully integrated into teacher candidates' thoughts on the nature of science and science teaching.

A Model for Incorporating the Benchmarks

In an effort to incorporate the benchmarks into my science methods course, I focused the course on the role of teachers in promoting scientific literacy for all students. The course familiarized teacher candidates with reform movements in science education, focusing particularly on Project 2061, the reform movement initiated by the American Association for the Advancement of Science (AAAS). Through hands-on experiences, teacher candidates learned to apply the principles of Project 2061 in designing and implementing curriculum, instruction, and assessment, and in evaluating resources and instructional programs. The course was divided among four phases, each building on the previous one.

Phase One: Confront and Challenge

The first phase of the course was designed to extend teacher candidates' knowledge and understanding of national reform movements in science education. The objective was

to confront each teacher candidates' conceptions of nature of science and science teaching. As Posner, Stike, Hewson, and Gertzong (1982) found *students tend to reject new information and even prevent new information from conflicting with existing conceptions.* Realizing that conceptions are difficult to change, the purpose of the first phase was to confront and challenge each teacher candidates' conception of science in order to structure the following phases of the course.

With the recognition that the understanding of the nature of science is a global conception that frames teacher candidates' understanding of science teaching (Bohm & Peat, 1989), the first activity was designed to confront and challenge teacher candidates' conceptions of the nature of science. The nature of science can be characterized as accepting that events in nature are knowable and predictable; that events that occur in nature are the same over time and can be applied to all parts of the world; and that knowledge is stable but also subject to change upon further evidence (American Association for the Advancement of Science, 1993). In order to elicit teacher candidates' conceptions of the nature of science, they participated in a cooperative controversy exercise designed to engage students in a debate of opposing conceptions of the nature of science (Hammrich, in press). Briefly, this exercise exposes teacher candidates to both traditional and new paradigms concerning the nature of science. Teacher candidates debate and reach consensus in groups on their conceptions of the nature of science based on their dialogue and reflections.

The second activity was designed to explore the existence of world views held by teacher candidates and discuss the impact of how world views influence the understanding of science. According to Kearney (1984) *The world view of a people is their way of looking at reality. It consists of basic assumptions and images that provide a more or less coherent, through not necessarily accurate, way of thinking about the world* (p. 41). Teacher candidates' world views were elicited by a questionnaire and concept map activity. Class discussion involved the nature of world views and the impact they have on

conceptions of science and teaching. Teacher candidates became aware of diverse world views and the impact that these differences have in students learning of science.

The third activity was designed to instruct teacher candidates on the notion of conceptual change. Teacher candidates watched the video "A Private Universe" (Schneps, 1987).The videotape gives an introduction to student misconceptions in science and provides a brief introduction to conceptual change teaching. Teacher candidates read chapter 13 in Science For All Americans (Rutherford & Ahlgren, 1990) and chapter 15 in Project 2061 Benchmarks for Science Literacy (AAAS, 1993) as a prelude to the integration of the teaching philosophy and methodology promoted by the benchmarks.

The fourth activity was to familiarize teacher candidates with Project 2061 benchmarks. For example, lessons were introduced on topics that presented methods of teaching based on the principles of Project 2061. Teacher candidates also practiced identifying central and related content and process benchmarks in various elementary lessons.

Phase Two: Application

The second phase of the course was designed to have teacher candidates apply the principles of Science For All Americans (SFAA) and the benchmarks in designing curriculum, instruction, and assessment. Teacher candidates analyzed model lessons showing how effective science instruction establishes connections across grade levels and subject areas. In this phase teacher candidates make curriculum and assessment decisions by drawing on knowledge and experiences from the earlier phase. The application phase allows the teacher candidates to experience and share in the shaping of their conceptions of science, teaching, and learning. Working in groups, teacher candidates are asked to decide on a science theme for a specific grade level, develop a rationale for their unit, decide upon central and related content and process benchmarks for each lesson in their unit, and develop authentic assessment measures for each lesson and the overall unit.

Phase Three: Evaluation

Phase three of the course was designed for teacher candidates to extend their learning by evaluating instructional resources and programs by applying the principles of in SFAA and Project 2061 benchmarks. In this phase, teacher candidates analyze and review current curriculum packages and materials to assess the match between the content and pedagogy of the materials with those of the benchmarks. As recommended by AAAS the steps for this activity included: 1. identifying benchmarks that appear important to the curriculum; 2. clarifying the meaning of the benchmarks; 3. analyzing how the curriculum addresses the actual content and pedagogy of the benchmarks; 4. estimating the likelihood that students will learn the benchmarks; and 5. rating the curriculum.

Phase Four: Sharing

In phase four, teacher candidates participated as teachers in carrying out lessons they designed utilizing the recommended content and pedagogy of the benchmarks. Teacher candidates designed lessons and match appropriate content and process benchmarks for six 4th grade classes in two Philadelphia elementary schools. In addition to implementing these lessons, teacher candidates also provided in-service instruction for the Bensalem School District . Based on their own experiences, teacher candidates successfully showed these elementary teachers how to incorporate the content and pedagogy addressed in the benchmarks.

Teacher Candidates Reflections

Teacher candidates feedback came in the form of their reflections about the course. These were revealed in many forms: class and small group discussions, informal questionnaires and interviews, and reflective journals. I have taken many of the following teacher candidates' responses from entries in their reflective journals in response to the specific activities outlined above.

Reflections of Phase One

By the time teacher candidates enter a science methods course they have already developed a conception of teaching and learning. Quite often they have not reflected on the nature of science. Additionally, they have not reflected on their own world view or the implications of world view on teaching and learning. Teacher candidates participated in activities that elicited their world views and their conceptions of science. The following excerpt describes a typical response as teacher candidates reflected on their conceptions of the nature of science. *Before we began the cooperative controversy activity, I was not real sure what my conception was of science...Granted I have taken all the necessary science courses during my college career but I have never really been asked to reflect or debate my conception of the nature of science...What I learned from the activity is that science is not as fixed or rigid as I had originally thought...science is more of a conquest of ideas, observations, and discoveries...By debating the two views of the nature of science, I was better able to reflect upon my own conception.*

Similarly, another teacher candidate expressed the extent to which she had not considered science before the exercise: *When I was asked in class to debate two views of the nature of science I thought this was an impossible task...for what did I know...As I began to get into the debate I realized that I knew more than I had thought I did...the activity forced me to critically think and reflect upon what I actually considered to be the nature of science...I think this activity was important for me because it laid a foundation for the rest of the class.*

Overall, teacher candidates reported that they had not thought about science to such an extent before and they came to have a greater appreciation of the complexity of science and scientific thought. This is expressed in the following students journal entry: *I always thought the nature of science was learning about the world to find out the right answers...I thought it was that simple...I have come to now appreciate the fluid nature of science which will definitely force me to reconsider how I view the teaching of science.*

In considering world views, teacher candidates also reported that they had not considered or reflected upon their own or other world views and how this might influence learning in science. For example, the following student indicated her conceptions of herself and science: *I guess I never realized that my world view impacted so much on my understanding of science as a way of knowing...I realized from the analysis that I have a world view that sees science as separate from nature and self...What this means for me as a teacher of science I am not sure...but I need to understand if I am to be conscious of various world views in my classroom.* In contrast, other students indicated a closer view of nature and self with science: *I found out that my world view sees nature as one with science...although I view science very much different from the science I learned in school... Perhaps there is hope for me yet...I mean I am open to seeing how I can incorporate my conception of science in school into my world view that sees science as one with nature.*

In viewing the video, "A Private Universe" teacher candidates explore the misconceptions both children and adults have that relate to scientific literacy. Teacher candidates are involved in a class discussion of what misconceptions are and how they effect the teaching and learning of science. The questions for the teacher candidates are: What is a misconception? Why do children and adults have misconceptions? What are the steps you would take in addressing a misconception? In response to these questions, most teacher candidates report how much the video and discussion open their eyes to the understanding of science as a process of discovery and that both children and adults develop their own conceptions based on prior experience and knowledge. The following three quotes illustrate typical reflections of teacher candidates:

- *I realized that I have the same misconception as the children and adults in the video concerning what causes the seasons...I remember learning about this in science but what puzzles me is why I still don't understand.*
- *I think a misconception is an idea that you have that is not correct...I must have many...I think students develop misconceptions because they never really learn the*

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concept in the first place...I know this is true for me...I remember memorizing information in science class but I guess I never really learned it.

- *I am learning in this class and in watching the video that you can't just tell a student the answer, they have to discover for themselves...I guess as a teacher I would provide experiences that challenge a students misconceptions and try to guide their understanding.*

After teacher candidates studied SFAA and Project 2061 benchmarks sections to help familiarize them with the goals of scientific literacy, they came to an understanding of how the content and pedagogy addressed in the benchmarks drive instruction. They also realized how woefully unprepared they were to teach the content of the benchmarks. The two students responses indicated below shows how these issues were central to their conceptual development of understanding the intent of the benchmarks:

- *I never realized how much I missed out on in school...Part of me is upset and part of me is happy to have gained the knowledge in order to better prepare future students in science literacy... At first it was real difficult figuring out what were the central and related benchmarks but after I started seeing the connection between the grades and seeing the overall themes it became apparent to me the overall picture...I sure wish they had the national standards when I was in school.*
- *I remembered the equation for photosynthesis but I didn't know what the equation meant...I can't believe it...I've been in school for almost 16 years and I never realized I didn't know what photosynthesis meant...As far as the content and process benchmarks, I guess I though science was just about content...I never realized their was so much process intvolved...I never realized that by just observing that I am actually performing a science process skill.*

Reflections of Phase Two

In the second phase of the course teacher candidates were asked to apply the principles of Project 2061 in designing curriculum, instruction, and assessment. This

phase was intended to have teacher candidates practice using the principles outlined in the benchmarks as far as addressing content and pedagogy. One teacher candidate noted and all others echoed this same sentiment, *I never realized that their was so much preparation and design in entire curriculum...This model of designing curriculum and assessment really made me question as to why I am teaching this unit, what is it that I want students to understand, and where are students coming from as far as understanding and where are they going...I guess I never gave much consideration as to what the grade before or after the one I was teaching was covering...This process has helped me see the big picture of understanding science and how conceptual learning is built upon prior knowledge...I also realized that teaching is not just simply telling but it is more of facilitating students own learning experiences.* Overall teacher candidates saw the importance of integrating curriculum in their own classrooms and across grades.

Reflections of Phase Three

In phase three, teacher candidates are asked to extend their learning by evaluating existing curriculum packages and materials according to the application of the principles of Project 2061. Over the course of six weeks teacher candidates worked in groups on their analysis of one curriculum package. Within their groups they meet each week, outside of class, to discuss and compare their results and ask questions. Teacher candidates' comments and reflections of this activity indicated that the analysis procedure was time consuming. Although, what they gained was an overall understanding of how to incorporate content and pedagogy into their curriculums. Sample comments included:

- *I felt that the analysis project was beneficial in that we worked in groups and could help each other by bringing different conceptions and points of view to the project. I also felt the analysis procedure itself was beneficial because it gave me an idea of what should be included in a science curriculum as far as content and pedagogy. I thought that having the benchmarks and very specific questions to compare them to was also beneficial.*

- *Although I think the curriculum analysis procedure is very time consuming, I now know that I can take a lesson and describe whether or not it is designed to match the intent of the benchmarks both process and content.*
- *The curriculum analysis process was extremely helpful up to a point. It was a good way to become more familiar with both the curriculum and the benchmarks, however, the pedagogical analysis section seemed superfluous. I suggest, instead of a critique of the pedagogy for each benchmark that there be a single pedagogical analysis which requires specific citations of appropriate benchmarks addressed by each category. This would appear to be more beneficial to those analyzing and using the analysis.*

Reflections of Phase Four

In phase four teacher candidates participated as teachers in carrying out lessons they designed utilizing the recommended content and pedagogy of the benchmarks to 4th grade students. At first the teacher candidates revealed frustration in completing the activities due to the amount of time they spent on soliciting student ideas and answering questions. For example, one teacher candidate commented: *I feel like the biggest obstacle in teaching lessons that address the intent of benchmarks is time factor... It seems like I never am able to finish an activity that I have designed...I find myself spending way too much time finding out what students know and listening to their questions...I know that finding out what students know is important but I only which it took less time.* The more teacher candidates taught lessons, they began to understand the importance of focusing on the process of students thinking skills as opposed to the end product. For example a typical response was *As I am teaching more and more lessons to the 4th graders I am realizing that it is not about getting to the end of the lesson just to finish it ... but that it is more important to focus of the process of understanding through exploration and discovery. This realization for me did not come easy but I am happy it did because I think I have finally conceptualized*

what the entire methods course was about concerning the understanding and teaching of science.

Summary

The call for systemic reform presents a great challenge to teacher educators in facilitating teacher candidates conceptions of what it is to teach effectively. Teacher candidates conceptions of teaching science are guided by their conceptions of science and the learning of science. In order for teacher candidates to model practices of teaching and learning as outlined by the standards movement, they need to participate in activities that cause reflection and they need to apply the benchmarks to lessons that they can or will use. First, teacher candidates need to confront their conceptions of science and scientific thinking. Secondly, they need to be familiar with the pedagogical philosophy addressed in the benchmarks that reflects current research in science education. Third, they must be familiar with the content of the benchmarks. Finally, teacher candidates need the opportunity to work with the benchmarks either through analysis of existing curricula or development of their own lessons and curriculum.

The teacher candidates' reflections revealed support for the use of this model in an elementary science methods course. After using this model as a way of incorporating the philosophy and intent of the benchmarks, I am convinced that using the framework of the benchmarks is both necessary and essential in demonstrating the importance of science standards in promoting scientific literacy for both our students and teachers.

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